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Atto-seconds Bunch Detection using Resonances of a Gas

Levi Schächter

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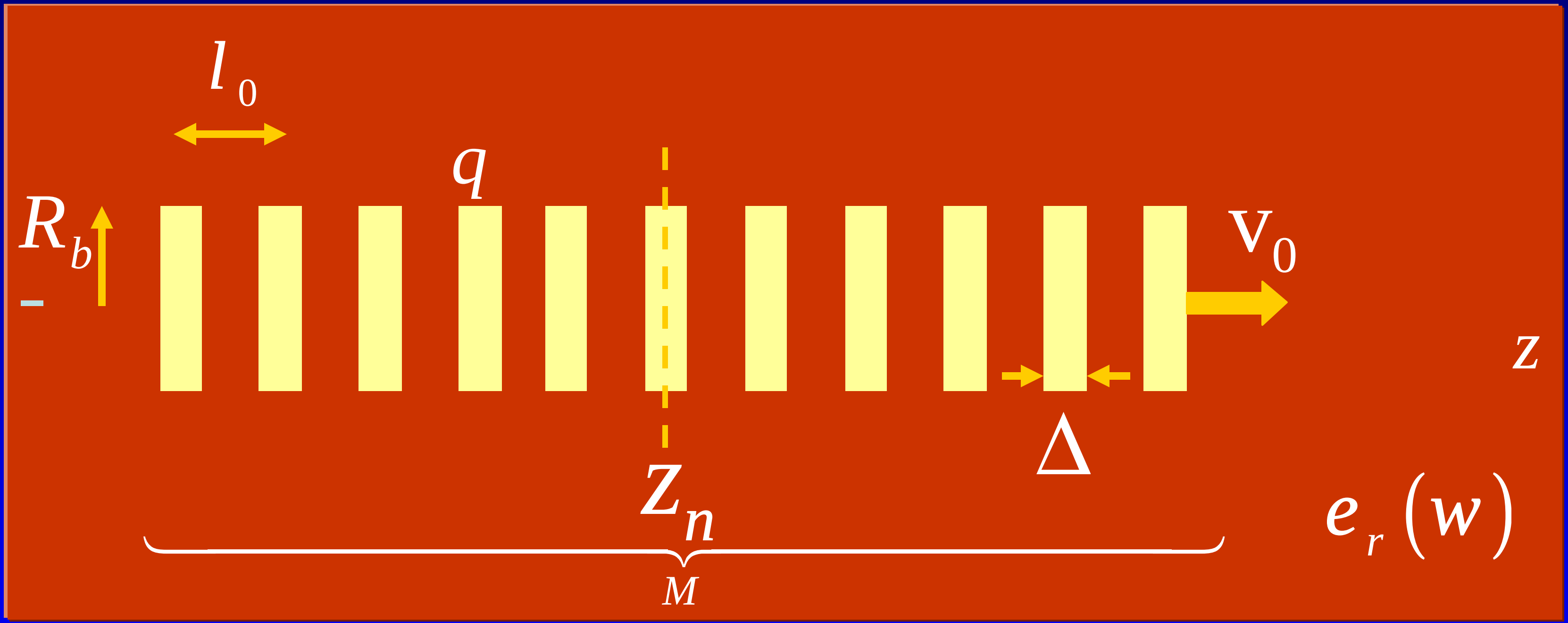
Train of Micro-Bunches

Simple Model



Assumptions

- Linear medium.
- Uniform and azimuthally symmetric micro-bunches.
- Constant velocity.
- No transverse motion.

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Resonant Medium

Plasma Frequency

$$\varepsilon_r(\omega > 0) = 1 + \sum_n \frac{\omega_{p,n}^2}{\omega_{0,n}^2 - \omega^2 + 2j\alpha_n\omega}$$

Resonance Frequency

Resonance Bandwidth

Assumptions:

- The medium has a single resonance.
- The medium is in the linear regime.
- No Cerenkov radiation.

Density of Population

$$\omega_p^2 = \frac{e^2 n}{m\varepsilon_0}$$

$$\omega_p^2 < 0 \Rightarrow \text{population is inverted}$$

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Energy Exchange

Technion
Israel Institute of Technology

$$\overline{\Delta E} \equiv \frac{\Delta E}{\left(4p\, r_e^2 d\right) mc^2 N_{el}^2 \sum_n n_n}$$

$$\approx \frac{\sum_n n_n \operatorname{sinc}^2\left(\frac{1}{2}\frac{w_{0,n}}{c}\Delta\right) F_\perp\left(\frac{w_{0,n}}{c}R_b\right)}{\sum_n n_n}$$

$$\approx \sum_n f_n \operatorname{sinc}^2\left(\frac{1}{2}\frac{w_{0,n}}{c}\Delta\right) F_\perp\left(\frac{w_{0,n}}{c}R_b\right)$$

Known distribution and resonances

$$F_\perp(u) \equiv \frac{2}{u^2}\left[1\text{-}2\mathrm{I}_1(u)\mathrm{K}_1(u)\right]$$

Energy Exchange

$$\overline{\Delta E} \approx \sum_n f_n \,\mathrm{sinc}^2\left(\frac{1}{2}\frac{w_{0,n}}{c}\Delta\right) F_{\perp}\left(\frac{w_{0,n}}{c}R_b\right)$$